

INDOOR AIR QUALITY ASSESSMENT

**Sumner Avenue Elementary School Annex
45 Sumner Avenue
Springfield, Massachusetts**



Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
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Background/Introduction

At the request of Judy Dean, Western Massachusetts American Lung Association, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA), was asked to provide assistance and consultation regarding indoor air quality at the Sumner Avenue Elementary School (SAES), 45 Sumner Avenue, Springfield, Massachusetts. Michael Feeney, Director of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA visited the school on June 16, 2002 and July 26, 2002 to conduct an indoor air quality assessment. Mr. Feeney was accompanied by Michael Foley of the SAES and Ms. Dean during the July visit. Mr. Feeney returned the SAES on November 8, 2002 to conduct follow-up evaluation and air monitoring. Reports of inadequate ventilation, odors, lack of temperature control and other indoor air quality issues prompted the assessment.

The school consists of two separate buildings: the original building and the annex. The annex is a two room, single story structure, built as a commercial building, possibly during the 1930s. Staff report that the building was used for several commercial purposes, including groceries and appliance sales. The annex contains two general classrooms and restrooms and was reportedly renovated in 1998. The SAES is a two-story, red brick building, consisting of two classroom wings and is the subject of a separate report.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551.

Results

The school complex houses kindergarten through fifth grades with a student population of approximately 350 and a staff of approximately 30. The annex contains two kindergarten classrooms with approximately 30 students and 4 staff. Tests were taken under normal operating conditions and results appear in Table 1.

Discussion

Ventilation

It can be seen from the table that carbon dioxide levels were below 800 parts per million parts of air [ppm] in classrooms during the July and November air monitoring. These carbon dioxide levels are indicative of an adequate fresh air exchange. Please note however that the building was unoccupied for several hours prior to testing. Reduced population and an operating ventilation system can serve to greatly reduce carbon dioxide levels and are not likely reflective of typical building conditions. Of note are the carbon dioxide measurements in the basement, which were above 800 ppm, indicating a carbon dioxide source within the building that was independent of occupancy and the ventilation system.

Fresh air in the annex is provided by a rooftop air handling unit (AHU) that was retrofitted to the building during the 1998 renovation project (see Picture 1). The AHU provides fresh air via ceiling mounted fresh air diffusers connected to ductwork. Air is returned to the AHU by a ceiling plenum that draws air through a series of grilles mounted in the ceiling. BEHA staff did not have a means of access to the roof to determine if the AHU has a means to exhaust air from the building or the condition of filters. Restrooms located in the rear of the building have ceiling-mounted exhaust fans activated by the light switch.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last servicing and balancing was not available at the time of the assessment. Since the system was added during the 1998 renovation, this system may have been balanced at that time. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see [Appendix I](#).

Temperature readings in classrooms (70° F) were within the BEHA recommended comfort guidelines. The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. Temperature control is difficult in an old building with abandoned or nonfunctioning ventilation systems. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The relative humidity measured in classrooms was 36 percent, which was also within the BEHA recommended comfort range. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Both classrooms, however, had relative humidity measurements (+3-4 percent) and the basement (+15 percent) higher than the relative humidity measured outdoors (33%) on the day of the assessment. This increase in relative humidity can indicate that a moisture source exists in the basement that may be drawn into the classrooms by the AHU. Possible sources of increased moisture in the basement include:

- 1) combustion products from the water heater (see Other Concerns section);
- 2) floor drain in the basement (see Other Concerns section); and/or

3) water penetration through the foundation (see Mold/Moisture Concerns section).

Limiting moisture is important since the sensation of heat increases as relative humidity increases (the relationship between temperature and relative humidity is called the heat index). As indoor temperatures rise, the addition of more relative humidity will make occupants feel hotter. If moisture is removed, the comfort of the individuals is enhanced. Removal of moisture from the air, however, can have some negative effects. The sensation of dryness and irritation is common in a low relative humidity environment. Humidity is more difficult to control during the winter heating season. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

As noted previously, the basement had increased relative humidity levels compared to outdoors. A likely source of moisture appears to be water penetration through the foundation. The building has shrubbery and other plant/foliage in close proximity to its exterior walls (see Pictures 2 and 3). The growth of roots against the exterior walls can bring moisture in contact with wall brick and eventually lead to cracks and/or fissures in the foundation below ground level. Over time, this process can undermine the integrity of the building envelope and provide a means of water entry into the building through capillary action through foundation concrete and masonry (Lstiburek, J. & Brennan, T.; 2001).

Another source that may allow water to penetrate through the foundation is what appears to be a former basement window pit located on the south exterior wall and the rear of the building (see Picture 4). Rainwater striking the south exterior wall will run off onto the ground at the base of the building and into this structure. This former window appears to be

sealed and was buried beneath soil. The configuration of this pit allows for water to accumulate within its brickwork as indicated by the erosion of soil beneath the exterior wall brick above the pit. Preventing water from coming into contact with the foundation in this area would help reduce potential water penetration into the basement through the foundation.

Other Concerns

A gas fired heater (see Picture 5) and water heater (see Picture 6) located in the basement. Due to the configuration of the water heater and its exhaust vent, carbon monoxide (CO) measurements were taken in the basement prior to and after activation of the hot water heater. No detectable levels of CO were measured in the basement or classrooms at anytime during this assessment. In addition, no detectable levels of CO were measured during follow-up testing conducted on November 8, 2002. Of note was a rapid elevation of carbon dioxide levels once the water heater was activated for several minutes in the area above the exhaust vent ducting during the July air monitoring. During the November visit carbon dioxide measurements in the basement were 700 ppm above classrooms levels with no occupants. The basement air measurements indicate that a carbon dioxide production source exists in the basement that is independent of occupancy.

In order to provide efficient combustion for the gas jet in the water heater and space heater that minimizes the production of CO, an adequate supply of combustion air is needed to provide oxygen. A combustion air vent is usually located in an area near the furnace. No observable combustion air vent could be identified in the basement.

The water heater and space heater are vented into a chimney by roughly horizontal ductwork (see Picture 7). The duct to the chimney connected to the gas water heater is also

approximately 12 feet in length and has an estimated 360° in turns of duct. In addition, ductwork to the chimney connected to the space heater is approximately 12 feet in length and has an estimated 360° in turns of duct. In general, exhaust ducts should minimize the numbers of horizontal pipes and turns. Increasing length and turns in exhaust ductwork can decrease the efficiency of products of combustion to the chimney. If this occurs, products of combustion can pool in the ducts. Water vapor mixing with other products of combustion can create corrosive materials that can degrade the metal of the ductwork. The rapid increase in carbon dioxide indicates that the duct connecting the water heater to the chimney may have holes, which can release products of combustion into the furnace area. Products of combustion then may enter into occupied areas through spaces beneath the basement door (see Picture 8) as well as other holes that lead to occupied spaces. Operating equipment that draws air from the basement (e.g. the AHU and restroom vents) may enhance the draw of combustion products into occupied areas of the building.

Please note the position of the space heater relative to the water heater. The exhaust vent for the water heater is not continuous (see Picture 5). Due to this configuration, products of combustion produced by the water heater can be drawn away from the vent system and directed into the basement when the space heater fan is operating.

The process of combustion produces a number of pollutants, depending on the composition of the material. In general, common combustion emissions can include carbon dioxide (CO₂), carbon monoxide (CO), water vapor and smoke. Of these materials CO can produce immediate, acute health effects upon exposure. The MDPH established a correction action level concerning CO in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a CO level over 30 ppm taken 20

minutes after resurfacing within the rink, that operator must take actions to reduce CO levels (MDPH, 1997).

The US Environmental Protection Agency has established National Ambient Air Quality Standards (NAAQS) for exposure to CO in outdoor air. CO levels in outdoor air must be maintained below 9 ppm over a twenty-four hour period in order to meet this standard. These NAAQS are used by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) as measures for assessing indoor air quality in buildings (ASHRAE, 1989).

A number of other conditions that can potentially affect indoor air quality were also observed. A possible source of odor is the basement floor drain. It is likely that this floor drain is rarely used, which can result in a dry trap. A trap forms an airtight seal when water is poured down the drain. A dry trap can allow for sewer gas to back up into the building. Sewer gas can be irritating to the eyes, nose and throat.

Conclusions/Recommendations

The conditions noted at the annex raise a number of indoor air quality issues. Based on the air tests conducted, visual inspection and reported complaints of occupants, measures should be taken to eliminate/minimize products of combustion within the annex. To this end, consider consulting a heating system engineer to examine and advise as to the appropriate measures needed to implement the following recommendations. In view of the conditions found in the annex at the time of the assessment, the following recommendations are made:

- 1) Install a wall-mounted CO alarm with digital readout in the basement stairwell. CO levels should be checked daily after the boiler is fired up during the heating season.

- 2) Seal the water heater and space heater ducts to prevent CO penetration into occupied space. Do not operate bathroom exhaust vents until the duct is sealed.
- 3) To overcome the length and bends (turns) in the water heater and space heater vents, a power fan on each duct should be installed in the ductwork/chimney to facilitate removal of pollutants to the outdoors.
- 4) Adequate combustion air needs to be provided for the water heater and space heater. A ground level fresh air intake may be necessary. Consult with the local fire prevention officer/building code officials to determine an appropriate method to provide combustion air for the water heater. If not feasible, consider replacing current gas water heater and space heaters with electric models.
- 5) Consideration should be given to rendering the basement as airtight as possible to eliminate the draw of combustion air to the occupied areas of the annex. These measures would include:
 - i) Installing weather-stripping along the doorframe of the basement access door.
 - ii) Installing a door sweep at the bottom of the door of the basement access door.
 - iii) Sealing the spaces around utility pipes that enter the occupied space through the floor.
- 6) Remove foliage at least five feet away from the foundation.
- 7) Improve the grading of the ground away from the foundation at a rate of 6 inches per every 10 feet (Lstiburek, J. & Brennan, T.; 2001).
- 8) Install a water impermeable layer on ground surface (clay cap) to prevent water saturation of ground near foundation (Lstiburek, J. & Brennan, T.; 2001).

References

BOCA. 1993. The BOCA National Mechanical Code-1993. 8th ed. Building Officials & Code Administrators International, Inc., Country Club Hills, IL. M-308.1

Lstiburek, J. & Brennan, T. 2001. Read This Before You Design, Build or Renovate. Building Science Corporation, Westford, MA. U.S. Department of Housing and Urban Development, Region I, Boston, MA

MDPH. 1997. Requirements to Maintain Air Quality in Indoor Skating Rinks (State Sanitary Code, Chapter XI). 105 CMR 675.000. Massachusetts Department of Public Health, Boston, MA.

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R 1910.1000 Table Z-1-A.

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0

SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.

US EPA. 2000. National Ambient Air Standards (NAAQS). . US Environmental Protection Agency, Office of Air Quality Planning and Standards, Washington, DC.
<http://www.epa.gov/air/criteria.html>.

Picture 1



AHU in Roof of SAESA

Picture 2



Shrubbery in Close Proximity to Exterior Wall

Picture 3



Plants Growing along Exterior Wall

Picture 4



Filled in Pit at Rear of Building

Picture 5



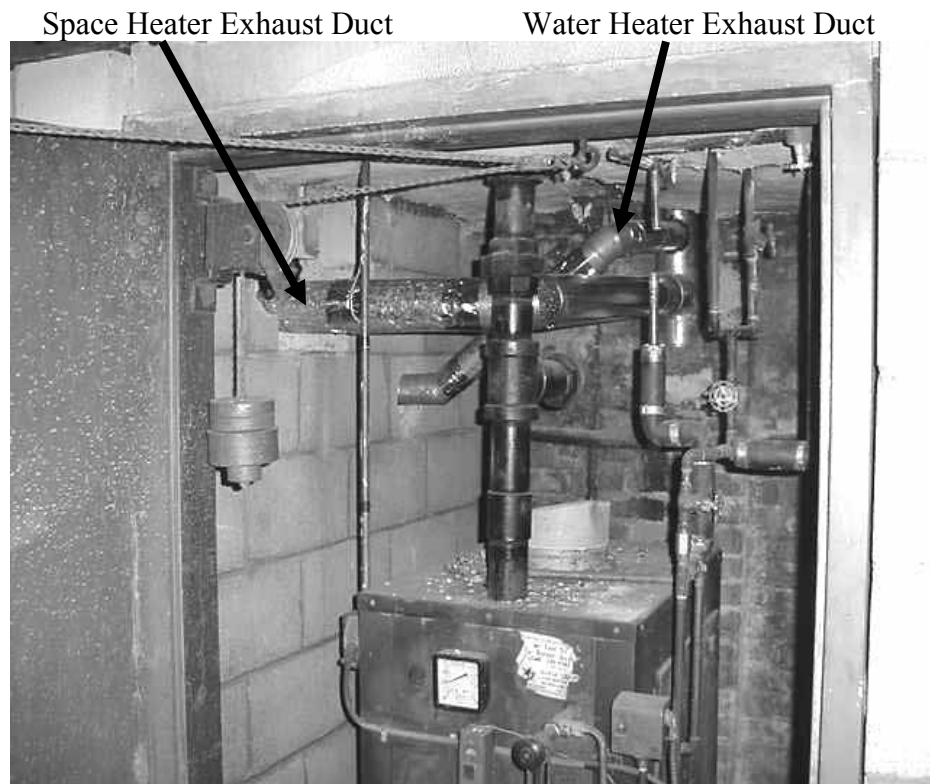
Water Heater in Basement, Note Exhaust Vent Duct

Picture 6



Space Heater in Basement, Note Exhaust Vent Duct

Picture 7



Exhaust Vent Ductwork for Water Heater and Space Heater, Note Number of Angles in Ducts

Picture 8



Space beneath Basement Door to Occupied Space

TABLE 1**Indoor Air Test Results – Springfield, Sumner Ave Elementary Annex****July 26, 2002**

Location	Carbon Dioxide *ppm	Carbon Monoxide *ppm	Temp °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
							Intake	Exhaust	
Background	423	0	72	33					
1	592	0	70	36	0	N	Y	Y	
2	589	0	70	37	0	N	Y	Y	
Basement	1110	0	75	48					
Basement (after water heater activation)	1548	0	75	47					

Comfort Guidelines

* ppm = parts per million parts of air
CT = ceiling tiles

Carbon Dioxide - < 600 ppm = preferred
 600 - 800 ppm = acceptable
 > 800 ppm = indicative of ventilation problems
 Temperature - 70 - 78 °F
 Relative Humidity - 40 - 60%

TABLE 2

Indoor Air Test Results – Springfield, Sumner Ave Elementary Annex

November 8, 2002

Location	Carbon Dioxide *ppm	Carbon Monoxide *ppm	Temp °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
							Intake	Exhaust	
Background	358	0	62	29					
1	549	0	67	28	0	N	Y	Y	
2	535	0	67	29	0	N	Y	Y	
Basement	1314	0	81	34					

Comfort Guidelines

* ppm = parts per million parts of air
CT = ceiling tiles

Carbon Dioxide - < 600 ppm = preferred
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 Temperature - 70 - 78 °F
 Relative Humidity - 40 - 60%